CLOSED VESSEL EXPERIMENT MODELLING AND BALLISTIC PARAMETER ESTIMATION OF GUN PROPELLANTS FOR LIFETIME PREDICTION

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Abstract — A closed vessel is an apparatus with very thick walls, in which propellants under test are burnt. After ignition, gaseous products and heat are produced. The time history of pressures is measured by piezoelectric transducers, and recorded in either an analog or digital way. For the design and simulation of a gun performance, it would be rather important if one could use the thousands of P versus t points generated by a single shot for the estimation of as many as possible ballistic parameters. The present work is devoted to the development of predictive models for the closed vessel, comparing the performance to real experimental data. Using known regression procedures (Maximum Likelihood, for instance), ballistic parameters are fitted and lifetime of the propellant can be predicted. This can be done once such parameters are related to its ageing process, which consists of a loss of volatile components.

Keywords — Closed vessel, propellant and ageing.

1. INTRODUCTION

A closed vessel is a robust pressure vessel used for propellant testing. The propellant is placed in the vessel, which is then sealed, and ignition is remotely commanded by a computer that, after ignition, also acquires pressure versus time data. Such ignition is promoted by an electric current on a filament that ignites a small amount of primer (in general, black gunpowder). Devices named squibs, stronger than electric pyrotechnic fuses, are also used for this purpose. Fig. 1 (extracted from the equipment manual) shows the exploded view of a closed vessel.

The modern trend to turn ordnance lighter and more efficient without decreasing reliability leads to a search for greater knowledge of the phenomena involved in propellant burning; in barrel / tube guns this involves estimating the actual ballistic parameters of the propellant in use.

Some of these parameters can be evaluated through thermochemical calculations as in the well-known Hirschfelder-Sherman method (1942, 1943). However, this approach has the disadvantage of requiring an accurate chemical description of the propellant, rather than using experimental data on pressure profiles to improve its quality. Ageing of the propellant continuously changes its composition, through irreversible auto-catalytic reactions in which volatile compounds are formed and evolve from propellant grains. Ageing is accelerated by humidity, by stockpiling temperature and by the loss of stabilizers. These facts reduce the mechanical integrity of propellant grains, producing pressure picks that are critical for safety of ammunition, rocket engines, cannons, mortars, etc... Therefore, in order to decide whether an aged propellant can still be used, it would be necessary to evaluate its actual chemical composition (by High Efficiency Liquid Chromatography, for instance), calculate its ballistic parameters through Hirschfelder-Sherman methods and use a gun simulation algorithm to predict the projectile muzzle velocity. Unfortunately, no analytical procedure is consolidated to elucidate propellant chemical composition and the approach is not used; instead, a heuristic criterion is traditionally employed.

Fig. 1. Exploded view of a closed vessel